

What is claimed is:

1. The method for calculating charged rate of a secondary battery which supplies electric power to loads, comprising the steps of:

measuring voltages of the secondary battery within predetermined period of time after termination of charge or discharge to obtain a plural measured voltages along time axis;

sequentially calculating the plural measured voltages to determine coefficients of a quadric or more exponential damping function which approximates time characteristic of an open circuit voltage of the secondary battery;

calculating a convergent value of the open circuit voltage of the secondary battery based on at least the coefficients determined; and

Calculating the charged rate based on the convergent value of the open circuit voltage.

2. The method for calculating the charged rate as claimed in claim 1, wherein predetermined terms included in the quadric or more exponential damping function are removed in correspondence to a standby time of measuring the plural measured voltages along the time axis to calculate the convergent value of the open circuit voltage of the secondary battery.

3. The method for calculating the charged rate as claimed in claim 1, wherein the exponential damping function is the function with time T as described below in the formula (1) which has five coefficients of A1, A2, A5, A6 and C:

$$F(T) = A1 \exp(A5 \cdot T) + A2 \exp(A6 \cdot T) + C$$

(1)

4. The method for calculating the charged rate as claimed in claim 1, wherein the exponential damping function is the function with time T as described below in the formula (2) which has nine coefficients of A1 to A9:

$$F(T) = A1 \exp(A5 \cdot T) + A2 \exp(A6 \cdot T) \\ + A3 \exp(A7 \cdot T) + A4 \exp(A8 \cdot T) + A9$$

(2)

5. The method for calculating the charged rate as claimed in claim 3 or 4, wherein the formula (3) mentioned below is used in place of the function F(T) when the standby time of voltage measurement is more than or equal to the predetermined first time, the formula (4) mentioned below is used in place of the function F(T) when the standby time of voltage measurement is more than or equal to the predetermined second time, and the formula (5) mentioned below is used in place of the function F(T) when the standby time of voltage measurement is more than or equal to the predetermined third time:

$$F(T) = A2 \exp(A6 \cdot T) + A3 \exp(A7 \cdot T) + A4 \exp(A8 \cdot T) + A9$$

(3)

$$F(T) = A3 \exp(A7 \cdot T) + A4 \exp(A8 \cdot T) + A9$$

(4)

$$F(T) = A4 \exp(A8 \cdot T) + A9$$

(5)

6. The method for calculating the charged rate as claimed in claim 1, wherein the charged rate of at least one of two or more secondary batteries is calculated.

7. The method for calculating the charged rate as claimed in claim 1, wherein the charged rates of at least two secondary batteries are calculated; and a display function which displays the charged rates of the secondary batteries and/or the determination of charge or replacement on each of the secondary batteries, or determination of ongoing use or not on the same, a storage function which records history of an individual battery, and a control and judgment function with a program to record the history of the determination and/or to determine repeatedly are included.

8. An apparatus of calculating charged rate of a secondary battery, which calculates the charged rate of the secondary battery to supply at least a load with electrical power, comprising:

a voltage sensor to measure voltage of the secondary battery;

a control part to execute and control the computing process for calculation of the charged rate; and

a storage part to store the voltage value output from the voltage sensor and the datum required for the computing process on the control part;

wherein the control part receives the output from the voltage sensor once or more within a predetermined period of time after termination of charge or discharge, stores the more than one voltage measurement value into the storage part, recursively calculates with the more than one voltage measurement value to be read from the storage part, determines the coefficients of a quadric or more exponential damping function to approximate the time characteristic of the open circuit voltage of the secondary battery, calculates a convergent value of the open circuit voltage based on the determined coefficients, and executes to calculating the charged rate from the convergent value.

9. The apparatus of calculating charged rate as claimed in claim 8, wherein the convergent value of the open circuit voltage of the secondary battery is calculated with the function obtained from the quadric or more exponential damping function by removing the predetermined term depending on the standby time of voltage measurement which is an elapsed time from termination of charge or discharge to starting to measure voltage.

10. The apparatus of calculating charged rate as claimed in claim 8, wherein there are determined the five coefficients of A1, A2, A5, A6 and C of the exponential

damping function with time T as described below in the formula (6), and that the convergent value is calculated with the function:

$$F(T) = A1 \exp(A5 \cdot T) + A2 \exp(A6 \cdot T) + c |$$

(6)

11. The apparatus of calculating charged rate as claimed in claim 8, wherein the exponential damping function with time T as described below in the formula (7) is used:

$$F(T) = A1 \exp(A5 \cdot T) + A2 \exp(A6 \cdot T) |$$
$$+ A3 \exp(A7 \cdot T) + A4 \exp(A8 \cdot T) + A9 |$$

(7)

12. The apparatus of calculating charged rate as claimed in claim 11, wherein the formula (8) mentioned below is used in place of the function F(T) when the standby time of voltage measurement, which is the time from termination of charge or discharge for the secondary battery to starting the voltage measurement, is more than or equal to the predetermined first time, the formula (9) mentioned below is used in place of the function F(T) when the standby time of voltage measurement is more than or equal to the predetermined second time, and the formula (10) mentioned below is used in place of the function F(T) when the standby time of voltage measurement is more than or equal to the predetermined third time:

$$F(T) = A2 \exp(A6 \cdot T) + A3 \exp(A7 \cdot T) + A4 \exp(A8 \cdot T) + A9$$

(8)

$$F(T) = A3 \exp(A7 \cdot T) + A4 \exp(A8 \cdot T) + A9$$

(9)

$$F(T) = A4 \exp(A8 \cdot T) + A9$$

(10)

13. The apparatus of calculating charged rate as claimed in claim 8, wherein the charged rate is calculated for at least one of two or more batteries.

14. The apparatus of calculating charged rate as claimed in claim 8, wherein the charged rates of at least two secondary batteries are calculated, and the apparatus comprises a display part which displays the charged rates of the secondary batteries and/or the determination of charge or replacement on each of the secondary batteries, or of ongoing use or not on the same, a storage part which records the histories of the individual batteries, and a control and judgment part with a program to record the histories of the determinations and/or to determine repeatedly.

15. The power supply system with secondary battery comprising the apparatus for calculating charged rate of a secondary battery as claimed in claim 8.

16. The power supply system for vehicle with secondary battery as claimed in claim 15, wherein the secondary battery is an automotive battery to supply loads on a

vehicle with electric power.